Claims

1. A method of creating an electronic data set of an average tooth that can be used for creating a dental prosthetic item, a tooth restoration, or a tooth model, comprising the following process steps:

a) generating a plurality of electronic data sets of a certain tooth type by scanning a predetermined minimum number of teeth of the same tooth type;

b) at least a certain number of correspondence points and/or correspondence structures that are characteristic for this tooth type are assigned in the individual electronic data sets;

c) taking into account said assignment of said correspondence points and/or correspondence structures in the individual data sets, an average value is created from the electronic data sets;

d) an electronic average data set derived from said average value is made available as an electronic representation of an average tooth having an average tooth surface with respect to the scanned teeth.

2. A method of creating an electronic data set of a generic tooth model that can be used for creating a dental prosthetic item, a tooth restoration, or a tooth model, having the following process steps:

a) scanning a predetermined minimum number of teeth of the same tooth type to provide a multiplicity of electronic data sets of this tooth type;

b) assigning at least a certain number of correspondence points and/or correspondence structures that are characteristic for this tooth type, in the individual electronic data sets;

c) carrying out a principal component analysis for the assigned correspondence points and/or correspondence structures of the scanned teeth;

d) carrying out a linear combination of at least a portion of the resulting principal components for the tooth type of interest and making this available as a generic tooth model data set.

3. A method as defined in claim 1 for creating a three-dimensional electronic data set of a generic tooth model, in which, after the assignment of the correspondence points and/or correspondence structures, the average data set is subtracted from all of the scanned tooth data sets, after which a principal component analysis is carried out for the difference data sets, a linear combination of at least a portion of the resulting principal components is carried out for the tooth type of interest, and this linear combination is made available, together with the average data set, as a generic tooth model data set.

4. A method of creating dental prosthetic items or tooth restorations, in which, for the reconstruction of a defective tooth or other defective dental prosthetic item, at least parts of the missing exterior surfaces of the dental prosthetic items or tooth restorations are built up by adapting an average tooth of the desired tooth type to the existing remaining tooth structure and/or opposing teeth and/or adjacent tooth state and/or bite registration, the average tooth being computed by averaging the electronic data sets of a relatively large number of scanned tooth surfaces of a specific tooth type, after the greatest possible number of correspondence points and/or correspondence structures between the data sets has been previously assigned, and the average value taken exactly between of the correspondence points and/or corresponding structures and therefore of the associated individual coordinates has been formed, after which the item is machined following appropriate adaptation.

5. A method of creating dental prosthetic items or tooth restorations, in which, for reconstructing a defective tooth or a defective dental prosthetic item, at least parts of the missing exterior surfaces of the dental prosthetic items or tooth restorations are built up by optimizing a generic tooth model data set of the desired tooth type to the existing

remaining tooth structure and/or opposing teeth and/or adjacent tooth state and/or bite registration, such that the linear factors of at least the most important principal components, which have been determined by principal component analysis methods from the electronic data sets of a larger number of scanned tooth surfaces, are varied such that the selected optimization criteria are satisfied by minimizing an error function, and, after successful adjustment to the remaining dentition condition and following creation of the data set, the reconstructed dental prosthetic item or the reconstructed tooth restoration is produced in a machine.

6. A method as defined in any one of claims 1 through 5, in which the assignment of the correspondence points and/or correspondence structures is carried out automatically.

7. A method as defined in any one of claims 1 through 6, in which, for the assignment of the correspondence points and/or correspondence structures, a weighted combination is used taken at least from height values and gradients and/or curvatures of the corresponding electronic data.

8. A method of using an electronic representation of an average tooth or generic tooth model, as obtained using a method as defined in any one of claims 1 through 7, as an electronic template for the creation of physical tooth models, tooth restorations, or dental prosthetic items using a machine that is controlled by the average data set, or generic tooth model data set, or by parts of these data sets.

9. A method of creating physical dental prosthetic items or tooth restorations for defective teeth or for defective dental prosthetic items, using an electronic representation of an average tooth, or generic tooth model, as obtained using a method as defined in any one of claims 1 through 7, comprising the following steps:

a) a three-dimensional scan of a preparation of the defective tooth or of a defective dental prosthetic item is carried out, and an electronic data set is created representing the preparation or defective dental prosthetic item;

b) characteristic correspondence points and/or correspondence structures are selected from the electronic information of the scanned preparation, or of the scanned defective dental prosthetic item, for the tooth type of the defective tooth, or for the tooth type appropriate to the defective dental prosthetic item;

c) the correspondence points and/or the correspondence structures in the electronic data sets of the scanned preparation or defective dental prosthetic item are assigned in accordance with the correspondence points and/or correspondence structures in the data set of the average tooth, or the generic tooth model;

d) the correspondence points and/or correspondence structures that are assigned to each other are approximated to the greatest extent possible using an optimization method;

e) the data set obtained by the optimization is made the basis of the reconstruction of the missing part of the defective tooth, or for building up the defective dental prosthetic item;

f) a physical dental prosthetic item or a physical tooth restoration for the defective tooth or for the defective dental prosthetic item is created using a machine that is controlled in accordance with the data set obtained in step e).

10. A method as defined in any one of claims 5 through 7 and 9, for creating a three-dimensional electronic data set of dental prosthetic items or tooth restorations, in which, after the correspondence points and/or structures of the defective tooth and/or the defective dental prosthetic item have been assigned to the generic tooth model data set, the linear factors for the portion of the principal components used are optimized, such that the new linear combination is adapted to the greatest extent possible to the correspondences, or is brought into register therewith.

11. A method as defined in claim 10, in which the linear factors are determined by minimizing the distances between the correspondence points.

12. A method as defined in claim 10 or 11, in which the linear factors are determined such that the probability for the determined linear combination is as high as possible.

13. A method as defined in any one of claims 9 through 12, in which said optimization takes into account the significance of specific correspondence points and/or correspondence structures in the form of weighting factors.

14. A method as defined in any one of claims 4 through 7 or 9 through 13, in which electronic data sets of a functional bite registrationand/or a static bite registration are taken into account.

15. A method as defined in claim 14, in which the information of the bite registration is taken into account in creating the correspondence points and/or correspondence structures for reconstructing the defective tooth and/or the defective dental prosthetic item.

16. A method as defined in claim 14 or claim 15, in which the possible regions of the contact points with the opposing tooth/teeth are determined as correspondence points and/or correspondence structures, in that, by superimposing the data set of the static/occlusal bite registration over the data sets of the functional bite registration, the regions showing short distances between the bite registrations are selected.

17. A method as defined in any one of claims 1 through 16, in which, for creating the correspondence points and/or correspondence structures for the reconstruction of the defective tooth and/or the defective dental prosthetic item, electronic data are included that are derived from at least one adjacent tooth and/or at least one opposing tooth and/or at least one symmetrically opposite tooth.

18. A method as defined in any one of claims 4 through 17, in which, using deformation and/or morphing, the data set that is determined by optimization is adjusted in the regions in which irregularities or interference occur with respect to the preparation and/or the remaining tooth structure and/or the bite registration and, if appropriate, the adjacent tooth

and/or opposing tooth.

19. A method as defined in any one of claims 1 through 7 and 9 through 18, in which the average data set, or the generic tooth model data set, is represented graphically such that the correspondence points and/or correspondence structures that correspond to the scanned preparation and/or defective dental prosthetic item and/or bite registration and/or adjacent tooth/teeth can be directly included in an electronic graphic representation of the average tooth data set, or the generic tooth model data set.

20. A method as defined in any one of claims 1 through 7 and 9 through 19, in which the average data set, or the generic tooth model data set, is graphically represented for indicating correspondence points and/or correspondence structures together with the scanned data sets of the preparation and/or defective dental prosthetic item and/or bite registration/positions and/or adjacent tooth/teeth.

21. A method of creating dental prosthetic items or tooth restorations, characterized in that

- a three-dimensional scan is carried out of a prepared tooth, or of a plurality of prepared teeth that are referenced in space with respect to each other,

- a three-dimensional scan of the opposing jaw in the vicinity of the preparations or, alternatively, of a functional bite registration in the region of the preparation or a static/occlusal bite registration is carried out,

- the measured data being stored as electronic digital data, and that

the bite registration(s) are referenced or registered in the same coordinate system on the basis of remaining tooth structure, adjacent tooth/teeth, or gums present in the vicinity of the preparation, after which the library tooth surface most suitable for this purpose, ie, the tooth surface found by minimizing an error function, is selected from a digitally stored tooth library on the basis of remaining tooth structure and/or by selecting specific correspondence points and/or

correspondence structures, this library tooth surface being fitted interactively and/or automatically using software routines to fit it to the remaining tooth structure, to the adjacent tooth or teeth and/or to the bite registration/opposing teeth, the missing external surfaces being built up by stipulating the position of approximal contact and/or oral and/or vestibular control points and appended to the marginal curves and/or preparation lines, so that the transition from the library tooth surface to the built-up exterior surface and from the built-up exterior surface to the remaining tooth structure in the vicinity of the preparation line is almost smooth, and, following creation of the data set, the latter is implemented to control a machine for creating the desired dental prosthetic item or the desired tooth restoration.

22. A method of creating dental prosthetic items or tooth restorations, characterized in that

- a three-dimensional scan is carried out on a prepared tooth, or on a plurality of prepared teeth that are referenced in space with respect to each other,

- a three-dimensional scan is carried out on the opposing jaw in the vicinity of the preparations or, alternatively, on a functional bite registration in the vicinity of the preparation or a static/occlusal bite registration,

- the measured data being stored as electronic digital data, and the bite registration/positions are referenced or registered in the same coordinate system on the basis of remaining tooth structure, adjacent tooth/teeth, or gums present in the vicinity of the preparation, after which the library tooth surface most suitable for this purpose, ie, the tooth surface that is found by minimizing an error function, is selected from a digitally stored tooth library on the basis of remaining tooth surfaces and/or by selecting specific correspondence points and/or correspondence structures, this tooth surface being adjusted interactively and/or automatically using software routines to fit it to the remaining tooth structure, to the adjacent tooth or teeth and/or to the bite registration or opposing teeth, regions where the library tooth surface overlaps the remaining tooth structure are cut off to

comply with the existing preparation limit, the missing external surfaces being built up by stipulating the position of approximal contact and/or oral and/or vestibular control points and appended to the marginal curves and/or preparation lines, so that the transition from the library tooth surface to the built-up exterior surface and from the built-up exterior surface to the remaining tooth structure in the vicinity of the preparation line is almost smooth, and, following creation of the data set, the latter is implemented to control a machine for creating the desired dental prosthetic item or the desired tooth restoration.

23. A method as defined in any one of claims 1 through 7 and 9 through 22, in which a tooth library of three-dimensionally scanned data sets of natural tooth surfaces is used, and a data set is created for each tooth surface, containing the tooth type and the associated correspondence points and/or correspondence structures, of which at least one part is used for the assignment to the corresponding correspondence points or correspondence structures of the remaining tooth and/or the preparation and/or the adjacent teeth and/or the opposing jaw and/or the bite registration.

24. A method of creating tooth restorations as defined in any one of claims 2 through 7 and 9 through 23, in which the abrasion of the tooth surface to be reconstructed is adjusted to suit the defective tooth and/or the defective dental prosthetic item and/or the remaining dentition condition, proceeding from the generic tooth model data set by varying the linear factors of the principal components.

25. A method as defined in any one of claims 21 through 24, in which the possible regions of contact points with the opposing tooth or teeth are determined as correspondence points and/or correspondence structures by superimposing the data set of the static/occlusal bite registration over the data set of the functional bite registration of the opposing jaw, and selecting those regions showing short distances between these bite registrations.

26. A method of creating tooth models or dental prosthetic items for prostheses, partial prostheses, practice models, training models, and/or demonstration models, in which the tooth surface of the tooth models or dental prosthetic items is formed using a generic

tooth model data set, or average data set, which is created, after the greatest possible number of correspondence points and/or structures have been assigned between the electronic data sets of a relatively large number of scanned tooth surfaces, by averaging these data sets and/or by principal component analysis, the linear combination of at least the most important portions of the principal components being formed for the generic tooth model data set, and the dental prosthetic item or tooth model is created in a machine or set up as a demonstration model in a printing device or holographic template.

27. A method as defined in any one of claims 1 through 26, characterized in that the surfaces of the data set of the dental prosthetic items, the tooth restoration, or the tooth model are smoothed prior to production in a numerically controlled machine in accordance with the tool geometries being used.

28. A method as defined in any one of claims 4 through 27 for creating a dental prosthetic item or a tooth restoration having a veneer, in which a data set obtained as in step e) of the method defined in claim 9 or as in claims 4, 5, 18, 21, or 22, is modified such that, for the areas corresponding to the zones to be provided with a veneer, a reduced shape is computed such that, during subsequent veneering, the distance of the new surface from the exterior surface of the reduced shape is virtually or precisely constant in at least a large proportion of the areas, and therefore the layer thickness of the subsequent veneer is virtually constant with few fluctuations.

29. A method of using a numerically controlled machine for creating tooth models, tooth restorations, or tooth dental prosthetic items, characterized in that the machine is controlled in accordance with a data set obtained according to a method as defined in any one of claims 1 through 28.

30. A device for changing a generic tooth model data set that is obtained as defined in any one of claims 2 through 7, having a control device which can change the linear factors of at least a portion of the principal components of the generic tooth model data set.

31. A device as defined in claim 30, having a display device which is coupled to the control

device and is adapted to afford a graphic display of the generic tooth corresponding to the generic tooth model data set and to show the effect of a change in the linear factors as carried out by the control device.

32. A method of creating dental prosthetic items or tooth restorations as defined in any one of claims 1 through 31, in which, after stipulation of, or automatic selection of, a few correspondence points between the intact remaining tooth structure and a generic tooth or average tooth or library tooth, adjustment takes place in an iterative manner, with the automatic adoption of a further number of corresponding points such that virtually all of the surface measuring points of the ground tooth material can be distinguished automatically from those of the unground remaining tooth structure, by implementing at least one distance check between the newly adjusted tooth surface and the defective tooth.

33. A method as defined in any one of claims 1 through 32, in which the preparation limit in the transition region leading from ground or removed tooth structure to unground or unremoved tooth structure is determined by using, as information, the transition region from smaller distance values to larger distance values between the defective tooth data set and the computed tooth surface, after carrying out computation of the tooth surface or supplementary adjustment of the tooth surface to the remaining tooth structure.

34. A method as defined in claim 33, in which the preparation limit in the immediate vicinity of the located transition region and/or within the located transition region is measured more precisely taking into account the areas of greatest curvature in these regions.

35. A method as defined in any one of claims 32 through 34, in which the distances between the electronic data set of the adjusted tooth surface and of the defective tooth data set are measured approximately in the projected direction of the path of insertion.

36. A method of creating dental prosthetic items or tooth restorations as defined in any one of claims 1 through 35, in which the desired preparation line is marked in sections in the electronic image of the defective tooth data set using a monitoring or control device, and for each section intermediate points on the surface of the data set are computed by

projecting a connecting line between the points that are selected by means of said monitoring and control device in the respective direction of view.

37. A method as defined in claim 36, in which the direction of projection can be selected separately by adjusting the desired view for each section.

38. A method as defined in claim 36 or 37, in which the connecting line is a straight line, any spline curve, or a parabola.

39. A method as defined in any one of claims 36 through 38, in which, between the clicked-on points, a connecting line is drawn through the points of the surface having maximum curvatures.

40. A method as defined in any one of claims 1 through 39 for detecting defective areas in tooth data sets for the machine-effected fabrication of tooth restorations or dental prosthetic items, in which the distance between the preparation limit curve, on the one hand, and a limiting curve of the reconstructed tooth surface, on the other hand, are computed point by point or section by section in arbitrary subdivided units, and only those points or sections are taken into account as part of the margin encompassing the defective area to be filled in in which the shortest distance from the other curve exceeds a given or adjustable threshold value.

41. A method as defined in claim 40, in which the segments of interest, selected from the two marginal curves, are assigned, sorted, and in part extended such that in each case a segment of the marginal curve of the reconstructed tooth surface and a segment of the preparation marginal curve together establish almost the entire periphery of the said defective area of interest.

42. A method as defined in any one of claims 1 through 41 for closing defective areas or holes in tooth data sets for the machine-effected fabrication of tooth restorations or dental prosthetic items, in which the surfaces to be built up are adapted as precisely as possible to the limiting curves of the specific defective area or hole, the gradients or curvatures of

the environment being continued smoothly and continuously in the marginal area, while given or selectable points or line or surface segments are interpolated by the surface to be built up.

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